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Combining qualitative evaluation and social network analysis for the study of classroom social interactions

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Abstract

Studying and evaluating real experiences that promote active and collaborative learning is a crucial field in CSCL. Major issues that remain unsolved deal with the merging of qualitative and quantitative methods and data, especially in educational settings that involve both physical and computer-supported collaboration. In this paper we present a mixed evaluation method that combines traditional sources of data with computer logs, and integrates quantitative statistics, qualitative data analysis and social network analysis in an overall interpretative approach. Several computer tools have been developed to assist in this process, integrated with generic software for qualitative analysis. The evaluation method and tools have been incrementally applied and validated in the context of an educational and research project that has been going on during the last three years. The use of the method is illustrated in this paper by an example consisting of the evaluation of a particular category within this project. The proposed method and tools aim at giving an answer to the need of innovative techniques for the study of new forms of interaction emerging in CSCL; at increasing the efficiency of the traditionally demanding qualitative methods, so that they can be used by teachers in curriculum-based experiences; and at the definition of a set of guidelines for bridging different data sources and analysis perspectives.

Keywords: Cooperative/collaborative learning; Evaluation methodologies; Learning communities; Post-secondary education

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1. Introduction

Design and development of Computer Supported Collaborative Learning (CSCL) systems is very complex, due to the diversity of implied actors and the variety of issues to consider: learning improvement, school organization, cultural problems, software design, distributed systems management, human-computer interaction, etc. This complexity demands appropriate methods of evaluation that let researchers and practitioners learn by applying innovative experiences and reflecting on them (Neale & Carroll, 1999). The application of computers to collaborative learning has been considered as a new resource for research in the field, due to their capability of logging interactions and processing them automatically. However, it also presents new challenges, mainly related to the appearance of new collaborative situations with new forms of interaction and to problems of automatic data management and interpretation (Guribye & Wasson, 2002).

In order to support the development of CSCL situations we proposed a conceptual framework named DELFOS (''a Description of a tele-Educational Layered Framework oriented to Learning Situations'') (Osuna & Dimitriadis, 1999). It defines an architecture for the design of CSCL applications and a development methodology based on the ideas of participatory analysis and design (Chin, Rosson, & Carroll, 1997), which emphasizes the role of formative evaluation in the development of information systems. We are currently working on the refinement of the methods and techniques defined in DELFOS for this formative evaluation. For this purpose, we draw on a situated learning approach that demands the adoption of an interpretative paradigm for evaluation. This perspective points out the need of studying the learning processes in their real contexts, taking the participants' perspective into account, and considers both individual and social aspects of learning (Wilson & Myers, 2000). In the previous version of DELFOS, evaluation was mainly oriented to the constructivist aspects of learning, focusing on the individual rather than on the social perspective. Therefore, we are now completing the evaluation method in DELFOS by defining a methodology and tools for evaluating social aspects related to participation in a community of learners.

A discipline that has showed to be appropriate for the efficient study of these social and participatory aspects of learning is Social Network Analysis (SNA) (Wasserman & Faust, 1994). SNA seeks to describe patterns of relationships among actors, to analyze the structure of these patterns and discover what their effects are on people and organizations. Several studies have demonstrated its value within the CSCL field for the study of structural properties of individuals learning in groups such as actors' prominence or network density (Cho, Stefanone, & Gay, 2002; Nurmela, Lehtinen, & Palonen, 1999). These studies usually take computer logs as an input, and process them with a SNA software package, such as UCINET (Borgatti, Everett, & Freeman, 1999). However, SNA by itself is not enough for achieving a full understanding of the problems, and needs to be complemented with other methods, like qualitative data analysis. Unfortunately, no guidelines have been provided in the CSCL literature regarding the integration of qualitative data and methods with SNA. On the other hand, existing SNA tools require a high level of expertise and they use proprietary data formats. An approach based on XML (W3C, 2000) for the representation of collaborative interactions, and its later processing by integrated automatic tools, could then offer a means to solve the problems of heterogeneity and integration in a systematic way.

We consider that the principles of qualitative case study research (Stake, 1995) constitute a good framework towards the integration of SNA methods in the evaluation of CSCL experiences from an interpretative perspective. This approach draws on naturalistic research methods able to deal with the subjective and complex nature of the studied phenomenon. Case studies performed under this perspective are based on the analysis of interactions of the participants in the contexts where these educational actions take place. These studies use ethnographic sources of data, such as observations, questionnaires and interviews, able to capture the perceptions of the participants. Quantitative data can be used to account for the occurrence of actions or events, and relate them with the qualitative categories. This combination of qualitative, quantitative and social network analysis methods places our proposal within the field of mixed methods of evaluation (Frechtling & Sharp, 1997).

In this paper we present a method that faces the new requirements posed by CSCL situations, enabling the integration of different sources of data and methods into qualitative case studies oriented to the formative evaluation of social aspects of learning. Part of the data comes from event logs of computer-based tools that students use to fulfill the course assignments, while other data are collected by traditional means (formal observations, questionnaires, focus groups). As an integral part of this method we present the tools we have developed in order to increase the efficiency and usability of the evaluation procedures. In order to exemplify the discussion, we present the method in the context of the classroom-based research project named LAO[1] (Dimitriadis, Martínez, Rubia, & Gallego, 2001), on which we have been working during the last three years. This project has been the platform for the conception and validation of the evaluation method presented in this paper.

The rest of the paper is structured as follows: the next section outlines the project to which the evaluation has been applied. Then, the research method and tools developed for its support are presented. The third section illustrates the use of the method for the study of one category extracted from the case study. We also elaborate on the advantages and limitations of the proposed methodology. Finally, we draw some conclusions and outline future lines of research.

2. Case study description: the LAO project

During the last three years we have been involved in a classroom-based research and development project aimed at the introduction of project-based learning with case studies and collaborative learning in a course of Computer Architecture in the studies of Telecommunications Engineering. Following the principles of the educational model of DELFOS as well as the directives of the IEEE/ACM Computing Curricula, the project aims to provide contextualized, integrated and meaningful knowledge; promoting active, intentional and collaborative learning. Besides these learning objectives, the LAO project served as a platform for educational research, where several issues related to the impact of the pedagogical design and tools on attitudes towards collaboration have been studied. The experimental work has taken place during the last three years, during the fall semester (September–February) of the academic years 1999–2000 to

[1] *Laboratorio de Arquitectura de Ordenadores* (Computer Architecture Laboratory in Spanish), which is the subject to which we initially applied the project.

2001–2002. The general design was validated during the first year. The revised project was extensively and systematically evaluated, in order to assess its effectiveness at fulfilling the aforementioned learning objective. General findings of this evaluation can be read in Dimitriadis et al. (2001). Here we present the main features of the project as they constitute the setting where we have applied and validated the evaluation design and tools. They are necessary to understand the example presented in Section 4.

The whole course is defined as a project that develops throughout the semester, whose objective is the design and evaluation of computer systems. In order to enable distinct perspectives of the subject within the classroom, five case studies (*clients*) are defined, covering different market sectors and system requirements. The teacher takes the roles of the different *clients* and the *director of the manufacturer companies*. Students work in pairs, and assume the roles of a *consulting firm* and a *computer manufacturer*. Each pair is assigned one out of the five case studies for the whole course, i.e. they *serve* only one of the five *clients*. This way, in each laboratory group of at most forty students, different *clients* are being studied throughout the course. The educational design aimed at promoting interaction within and between the pairs assigned to different *clients*.

The project is divided into three subprojects that study different specific issues of the whole problem. Every subproject presents two milestones. In the first one, basic decisions are taken, and in the second milestone, each pair has to submit a formal technical report to the *client* (teacher). In each milestone, each laboratory group holds a debate, designed as a collaborative review of the work of the students, and where the problems of the different *clients* can be shared and discussed at a laboratory group level. At the end of the whole project, a technical report is collaboratively produced among all pairs that deal with the same case study in each laboratory group.

Several tools are used to support the project. BSCW (Basic Support for Co-operative Work) (Appelt, 1999), a well-known shared workspace system based on web interface, was used for asynchronous document sharing and threaded discussions. Of special interest here is the fact that BSCW logs every action performed on the shared workspace, providing data that were used as a source of the analysis, as explained in the following section. Other tools, like e-mail for communication and simulators for the assignments are also used during the process.

The next section presents the method that was applied for the evaluation of the research objective of the LAO project, while specific findings in the LAO case study are presented in Section 4.

3. Mixed evaluation methodology for the study of social aspects of learning

The evaluation method proposed in this section tries to give an answer to the new requirements posed by CSCL to the problem of formative evaluation. We outline briefly these issues before proceeding with the description of the method, as they are important to understand the motivations of the proposal.

An important consequence of the use of computers to support collaborative learning is the fact that many researchers see in them an opportunity for evaluation, due to their storage and processing capabilities. This way, log files provided by the computer are nowadays a common source of data, normally combined with more traditional ones. However, CSCL has also introduced new challenges to the evaluation of collaborative learning, like how to deal with the wide variety of

interaction types that appear in these settings; how to make log data easily available to researchers, allowing them to configure the evaluation; how to perform data processing by automatic means; and how to present results in an intuitive format. Additionally, all of these problems have to be addressed from an interpretative perspective, which creates the need for studying issues related to the context where learning is taking place, and for considering the perspective of participants.

For addressing these problems, we propose a mixed evaluation method, as depicted in Fig. 1. It uses several sources of data and analytical methods, and is supported by automatic tools to increase the efficiency of the overall process. This section focuses on the explanation of these elements.

3.1. Data sources

The method uses ethnographic data from a variety or sources. It combines different *questionnaires*: *general questionnaires* at the beginning and end of the course, with open and closed questions regarding the evaluation objective; *students' post hoc comments* to get their short-term impressions after meaningful activities or events; *students' criticisms* of the educational project, submitted as appendices to the reports, in order to get their subjective view of the project; and finally, *sociometries* were students list the names of those with whom they have had some kind of relationship. These sociometries can be done several times during the year, and at least once at the beginning of the course and once at the end of it. *Focus groups* sessions are held with a group of volunteers at appropriate milestones, including the beginning and the end of the course, in order to gain insight into the students' point of view; *classroom non-participant observations* where

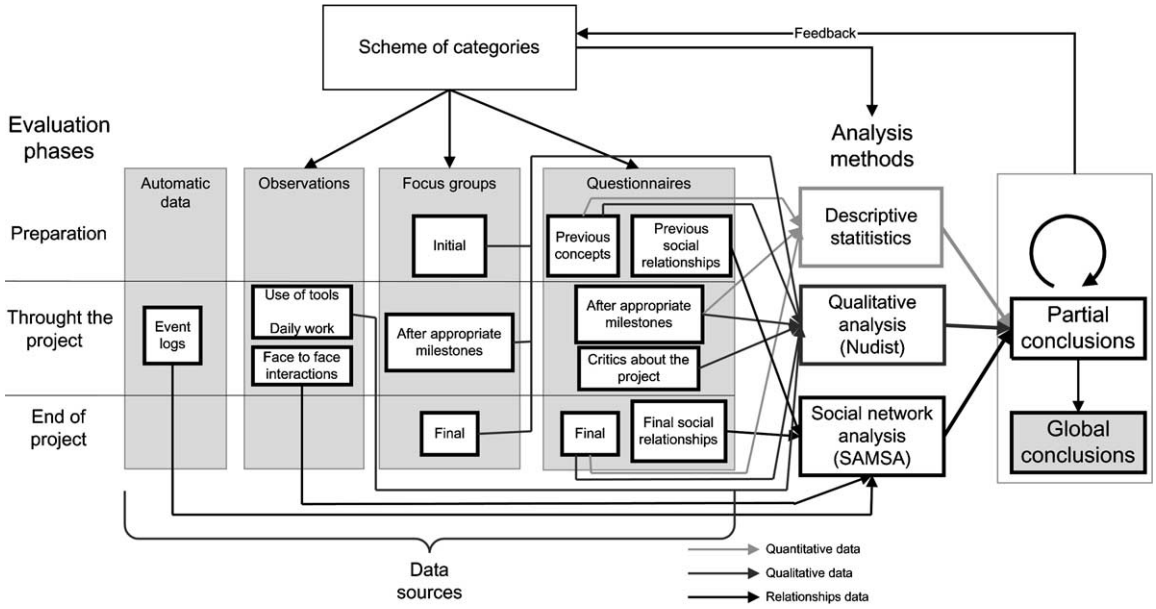

Fig. 1. The proposed mixed evaluation scheme: data sources, methodology, timing and analysis tools. Arrows show information flow paths.

an observer takes note of the different interactions and attitudes towards participation in the students' daily work at the laboratory. Finally, *log files* register the interactions which occur through the CSCL tool that is being used. While interviews and questionnaires are more suitable for acquiring a participant's perspective of the problem, data collected automatically and observations are better for measuring the actual use of the tools and the interactions arising from it. This variety of sources aims at supporting a data triangulation scheme that considers the new requirements of CSCL settings.

Part of this data is processed by software tools, as explained in Section 3.3. It is important to note that the use of these tools requires the data to be described at an appropriate level of abstraction, suitable for being processed by a computer. We have chosen XML (W3C, 2000) as the data representation format. The main reasons for this choice are self-descriptiveness, standardization, and interoperability. XML files are easy to understand and produce, as they follow a syntax that is defined by means of a DTD (Document Type Definition). In our proposal, the DTD describes in an abstract manner the different types of interaction that can be encountered in CSCL scenarios. By defining this DTD, we are providing a unified representation of the distinct sources of data, and thus avoiding the cumbersome data transformation processes typical in scenarios with different data and tools. Moreover, being a generally accepted standard, developers of tools can take advantage of the increasing number of technologies based on XML; while final users (teachers, researchers) might benefit from the integration of the proposed tools with generic web technologies or another system based in XML. Further details about the DTD and its use to support evaluation can be found in Martínez, de la Fuente, and Dimitriadis (2003).

3.2. Description of the method

The method we are proposing is based on the principles of case study research. As explained beforehand, the study of CSCL situations needs to be done from an interpretative standpoint, which aims at understanding each experience taking into account its context and evolution. Among qualitative methods, case studies are appropriate for evaluations, as they deal with the intensive study of one or few examples of certain phenomenon. This section explains how to adapt the generic phases defined for case studies (Stake, 1995) to the mixed scheme we are proposing.

As shown in Fig. 1, the evaluation starts with the definition of a scheme of categories. This can be done empirically, based on the results of past experiences, or theoretically, according to the specific evaluation objectives. The scheme evolves throughout the study, by the specialization of existing categories or the addition of new ones that emerge from the analysis.

Qualitative analysis is fed by qualitative data sources (open questionnaires, observations, focus groups). Partial qualitative analysis is performed though the accumulation of data related to each category and from direct interpretation processes.

Quantitative analysis of closed questions is performed in order to account for occurrences of facts, possible problematic points, etc. It consists of simple descriptive statistical analysis assisted by any of the currently available statistical packages. The purpose of these studies is not to demonstrate hypothesis, as it would be in a positivist approach, but to detect general tendencies in an efficient manner, which are confirmed or discarded by triangulation with the other two analysis methods.

We have identified a set of SNA indicators for the study of participatory aspects of learning: *Network density* (D), *actor's degree centrality* [$C_D(n_i)$], and *network degree centralization* (C_D) (Wasserman & Faust, 1994). D measures how knitted a network is, with values ranging from 0 (most sparce) to 1 (most dense). *Degree centrality* is an index of the actor's prestige. Given an actor n_i, $C_D(n_i)$ is the proportion of actors that are adjacent to n_i. It reflects the activity of the actors. In the case of directed relationships that consider the direction of the link, two degree indexes are defined: *indegree*, or the number of links terminating at the node; and *outdegree*, or the number of links originating at the node. Finally, *network degree centralization* (C_D) is a group-level measure based on actor's degree centrality. It gives an idea about the dependency of the network on the activity of a small group of actors. Its values range from 0 (even distribution of activity) to 1 (most centralized network). Directed networks define the corresponding indexes of indegree centralization (C_{ID}) and outdegree centralization (C_{OD}). All of these indexes and ranges apply to dichotomous relationships, that can have only one out of two possible values: 0 when there is no link and 1 when there is a link between two actors. It is also possible to consider valued relationships, that include a number showing their strength. The indexes computed on these relationships are more difficult to generalize than those computed from the dichotomous relationships, but sometimes are important to provide additional information. All of these indexes provide basic information about the activity of the actors in the network and about the global structure of the network according to different relationships. Moreover, they are simple to understand and to interpret, which are important features for facilitating their use by evaluators, who are not expected to be experts in SNA methods.

In order to perform social network analysis, we need to define the networks and relationships to which the study is to be applied. We have defined three generic types of social networks: *direct relationship networks*, built from relationships between two actors; *indirect relationship networks*, built from relationships that have been established through a shared object (like the creation and further reading of a document); and *use of resources networks*, that relate actors and objects. These generic networks have to be particularized for each situation through the definition of the set of actors and sources of data. In our scheme, these sources include data collected by automatic means (system logs) and ethnographic data coming from observations and sociometric questionnaires. We should note that the use of different data sources, as well as in the overall evaluation scheme, complements the information and provides for a more thorough and reliable understanding of the processes.

A relevant feature of social networks is that they can be visualized as graphs called *sociograms*, which represent the actors as nodes of the graphs and the links among them as lines in the graph. A convenient representation of sociograms is produced by the use of Multidimensional Scaling (MDS). MDS maps the similarities among actors, so that those that are similar to each other in the input data appear closer in the graph, and vice versa. Using geodesic distances as a measure of dissimilarity, a sociogram will show in an intuitive manner subgroups of inter-related actors, and some relevant positions, such as the more and less prominent actors (Wasserman & Faust, 1994).

The overall evaluation process evolves cyclically so that in the first phase each one of the analysis methods is performed independently, yielding partial conclusions that can be confirmed or rejected by triangulation or can produce a new cycle of the evaluation process, in order to gain insight about an emergent aspect. The evaluation is a longitudinal process that evolves

throughout the course. Its main products are the refinement of the initial scheme of categories as well as formative changes to the pedagogical design.

3.3. Supporting evaluation tools

The proposed evaluation scheme is supported by three software tools: QUEST, SAMSA (System for Adjacency Matrix and Sociogram-based Analysis), and Nud*IST. Additionally, any statistical package can be used for the quantitative analysis. Fig. 2 shows their use in the overall analysis method, which will be outlined in this section.

QUEST (Gómez, Dimitriadis, Rubia, & Martínez, 2002) allows for the design of questionnaires by a teacher or researcher, and their presentation as web-based forms to the students. QUEST collects the results automatically and converts them into different formats: RTF files for their use with Nud*IST, spreadsheet files for quantitative data analysis, and XML files representing the interactions for SNA. We should point out that these automatic conversions of data are simple, but very necessary for improving the efficiency of the whole process.

SAMSA[2] supports social network analysis automatic processing. As shown in Fig. 2, it contains several input modules (`obs2xml`, `el2xml`), that take data from different sources (observations and event logs respectively) and transform them into the XML file representing the interactions. Then, SAMSA allows the researcher to select and configure the network she wants to study (selecting dates, actors, and type of relationship). The tool builds the matrix that represents the network, known as *sociomatrix*, and computes the indexes chosen by the researcher. It also shows the sociogram representing the network, and allows for the visualization of the actors'

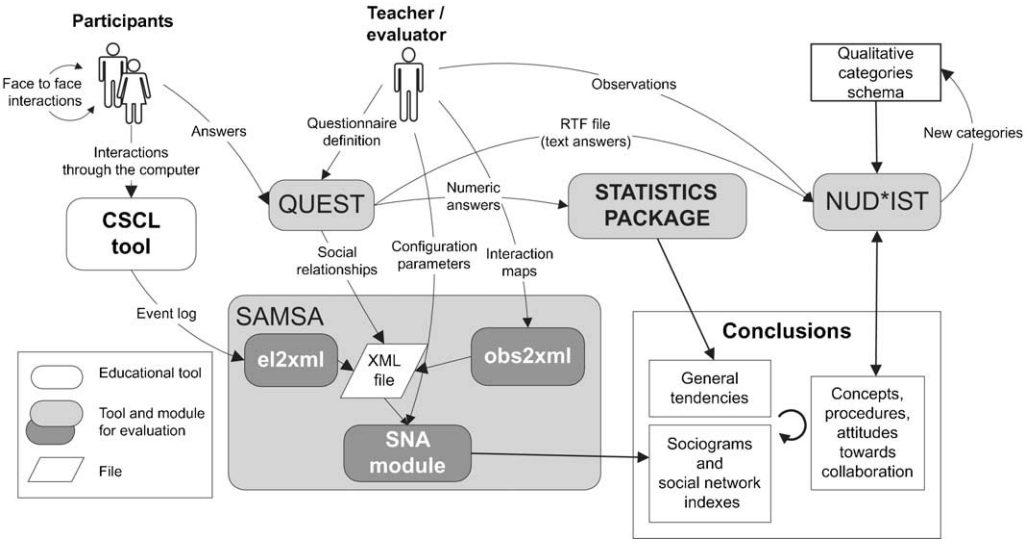

Fig. 2. The proposed analysis tools, as related to the potential actors (students, researcher, teacher), showing information flow during educational research.

[2] Named after the subject of Kafka's *Metamorphosis*.

attributes. SAMSA supports the aforementioned SNA measurements that have been identified for our evaluation purposes.

The overall evaluation procedure is supported by a third tool, Nud*IST (QSR, 1997), a well known qualitative data analysis package. As explained in the previous section, the qualitative analysis is at the core of the process, and therefore, this tool receives data from the rest of the elements of the system (Figs. 1 and 2). It takes direct input from QUEST (free-form questionnaires in RTF format), as well as the transcriptions of the observations and the focus groups.

The data sources, procedures and tools described in this section constitute our proposal for a mixed method of evaluation. SNA has been introduced due to our interest in the study of participatory aspects of learning, and quantitative data is used in order to detect general tendencies. Finally, qualitative analysis provides insights into the participants perspectives and the context of collaboration. All the methods are fed with data coming from different sources, meeting the need for capturing the different forms of interaction that arise in computer-network supported classrooms. This way, we provide for method as well as data triangulation that will lead to an increase of evaluation reliability. The need for unifying the different data sources has led us to propose the use of XML and the subsequent definition of a DTD that models different types of collaborative interaction. The next section will illustrate the use of this system with an example related to the LAO project.

4. Collaboration as sharing information: an example of the method in the LAO project

The method proposed in the previous section has been applied to the educational and research project described in Section 2. In the present section we illustrate the proposed scheme using a specific example that focuses on a category (*collaboration as sharing information*) that is especially relevant within the context of the educational research objective of the project.

4.1. Evaluation data and procedures of the experience

The example presented in this section has been extracted from the general results of the fall 2001 case study, applied to a course in the fourth (out of 5) year of the studies carried out in the Telecommunications Engineering School at the University of Valladolid, Spain. The class of 100–120 students was divided into three sessions of 40 students (maximum), in which the elementary unit consisted of groups of two students (pairs). The 15-week long semester corresponded to three subprojects of 4 weeks each, with reviews (synchronous debates) taking place every 2 weeks. Elaboration of the final report started in the sixth week. The final report was to be submitted a month after the course had finished, and therefore, during this period, there were no lectures where students could meet face to face.

The main issue of evaluation was to know if these innovative methods would succeed in developing new concepts, attitudes and procedures towards collaboration, in the context of the passive and individualistic culture of Spanish universities. We were also interested in the role of computer-based tools in this potential change of perspective. It is important to note that this section does not aim at presenting the whole evaluation process, but at illustrating the main features of the method with an example. The description of the complete evaluation process can be found in Martínez (2003).

In order to show the use of the method we will focus on the study of a single category, "*collaboration as sharing information*". This concept is of special interest in our educational setting for several reasons. First, the emergence of a community of learners requires the free flow of information in the group, where everybody has the feeling (and the certainty) that they can access important data available in the community. This was a major challenge in our project, as the previous experience of the students was closer to that found in traditional classrooms, where information is expected to flow mainly between teacher and students. Second, computer supported collaboration in the project takes place mainly through information sharing: BSCW can be used to share reports, papers, URLs and other information resources, and students were strongly encouraged to do so by the teacher. And finally, the educational project was also designed in order to promote these sharing interactions. The students were asked to write the final technical report among all the pairs of each laboratory group dealing with the same *client*, thus requiring them to share (at least) their subproject reports. They were also asked to compare their solutions with the rest of the *clients*, which was itself a means of encouraging the students to access other pairs' information.

The evaluation followed the general scheme presented in Section 3, adapted to the particular characteristics of the project. Formal observations took place every week in one of the laboratory groups, and five focus group sessions were held with 10 volunteers. Questionnaires were submitted to the students according to the evaluation design, and BSCW events were logged during the course. A number of social networks were constructed to inspect interactions. The example presented in this section aims at showing how these different sources of data, methods and techniques of analysis provide a better understanding of the concept under study.

4.2. Analysis procedures

Before the course started, previous concepts related to collaboration were inspected through two questionnaires, a *sociometry* that aimed at establishing an initial social network of previous collaboration relationships in the classroom, and a *general questionnaire* where students could express their perception of the collaborative environment. The same two questionnaires were repeated after the course had ended. Response ratio decreased during the course, and some students who had answered the initial questionnaires did not answer in the final ones. The computation of the quantitative and social network analysis indexes took these facts into account by including only data coming from students who had answered the initial and final questionnaires. This pre-selection was not applied to the qualitative analysis of open questions, which considered all the answers provided by the students.

The answers to the sociometries were processed with SAMSA, yielding two networks whose density is shown in Table 1. Looking at the first column, we can observe that the previous collaborative experience of the students did not include *sharing information* as a main form of collaboration (this concept is the least dense, with $D_i = 0.29\%$), whereas *resolving doubts* and *creating a product in common* were the most dense relationships. In addition, in the general questionnaire only a few students regarded the classroom environment as collaborative (16.5%), and others (30.6%) said that collaboration happened only with friends. Surprisingly, most pairs (75 vs. 10) declare themselves motivated to work in a group. This points out an apparent contradiction: they appreciate collaboration as an abstract value, but their previous experience is rather poor and does not actually tend towards collaborative attitudes.

Table 1
Density measurements from the networks built from questionnaires (D_i: initial questionnaire network density; D_f: final questionnaire network density)

Relationship	D_i (%)	D_f (%)
Discussing	0.34	0.48
Solving doubts	0.43	1.11
Sharing information	0.29	0.53
Create a product in common	0.77	0.82

The two questionnaires allowed us to study the overall evolution of the concepts. Regarding the relationships questionnaire, the density of all activities increased significantly, notably *sharing of information*, almost doubling its value. Positive results also appeared in the final *general questionnaire*, where the same question about classroom collaboration environment has the following distribution: 6.8% very competitive; 18.2% competitive; 9.1% indifference; 40.9% only with friends; and 25% overall collaboration. This initial observation reflects the positive impact of the educational project, but needs to be confirmed by other analysis tools in our methodology.

With respect to the means for information sharing, BSCW offers a shared workspace where students were encouraged to publish their documents and notes, while the teacher used it to deliver documents and comments to the class. An obvious question that emerges is whether, in fact, BSCW contributed to the aforementioned development of collaborative attitudes regarding information sharing. In order to answer this question, a social network was constructed on the basis of *indirect relationships* that stem from posting and reading others people's documents, so that a link between n_i and n_j represents n_j accessing an object created by n_i. The two networks, one including the teacher and other leaving him out, will allow to test his overall influence in the use of BSCW. Table 2 shows density and centralization indexes of the networks, divided in four periods: the three subprojects (sp1, sp2, sp3) and the final project (spf). The three columns to the left show the results of the network including the teacher, while columns to the right, the results without him.

Both networks show that density decreases along time, during the three subprojects. The low use of BSCW in this period of the course was confirmed by mid-course, through a questionnaire performed in one of the milestones (*post-review questionnaire*), in which students were asked if

Table 2
Indexes from the BSCW indirect interactions network

Period	Without teacher			With teacher		
	D (%)	C_{OD} (%)	C_{ODv} (%)	D (%)	C_{OD} (%)	C_{ODv} (%)
Sp1	17.65	31.14	115.57	21.93	82.41	374.38
Sp2	13.73	66.43	88.93	17.54	87.03	1668.21
Sp3	10.13	26.64	137.02	14.33	72.84	226.85
Spf	31.05	29.41	157.79	35.38	68.21	775.31

D: density; C_{OD}: outdegree centralization of dichotomous network; C_{ODv}: outdegree centralization of valued network.

they *intended* to post their notes and intermediate documents in BSCW, and a latter questionnaire asking if they actually did so and why. Surprisingly, 20 pairs expressed their intention of sharing their documents, but just three of them did it. When asked in the following milestone through an open-ended questionnaire about the reasons of this contradiction, they argued lack of time or confidence in their contributions.

Nevertheless, the table shows a sharp peak of density in the period of the final project. This increase of activity is explained by several reasons: at this time of the year they were in examination period without lectures, and therefore, they could not meet face to face. They started to post drafts, notes, comments, and numerical results in BSCW and read almost all the documents posted by other pairs having the same *client* (i.e. the same case study), which supports the idea that *collaboration as sharing information* develops partially influenced by the relationship of *collaboration as generating a common product*.

On the other hand, outdegree centralization (C_{OD}) gives an idea of how balanced the creation of documents was, which can be regarded as active sharing of information. Observing the columns at the right that show the indexes of the networks that include the teacher, it is possible to see that he has a strong influence, with a peak in the second subproject (sp2), where 87% of the network activity depends on one single actor (the teacher). Observing the high value of the index calculated on the valued network (1668%), we can observe that during this period the teacher created a high number of documents, in contrast with the students. By inspecting the XML translation of the BSCW logs, we could easily verify that during this period, the teacher published articles and comments regarding the first subproject reports, that were read by all the students. Centralization in these networks decreases throughout the following phases, remaining over 50% with C_{ODv} very high in the final project (spf), when the teacher published comments to the successive versions of the final reports submitted by the students. These comments were massively read by the students, which explains this high index. On the other hand, the indexes of the networks at the left, that do not include the teacher show a more balanced distribution (C_{OD} around 30% except for sp2), although they still show that the activity of the students was unevenly distributed, with an actor present in almost a third of the total of relationships of each network.

Sociograms complement the information of the tables above, showing at first glance an idea of how the different actors (pairs, in this case), are situated with respect to the relationship. Fig. 3 shows the sociogram of the indirect relationships network during the fourth period of the course, while students were preparing the final project report, with the teacher (x00) included in the network. We can observe several interesting features: First, the network shows a connected graph (all nodes are directly or indirectly accesible among them), which was not the case with other networks built from the questionnaires and from the maps of interactions taken in the observations. Therefore, a first conclusion is that BSCW succeed at eliminating obstacles between the students. Second, we see that, in spite of the teacher being the most central actor as explained beforehand, some pairs (x26, x34, x23, x39) occupy central positions in the sociogram.

Inspecting the logs, we could see that some of these pairs had published notes and comments during the course, which were massively read by the rest of the students. Thus, these central students could be identified as being the information "sharers" of the class. Third, pairs are placed near others that share the same *client*, due to the fact that in this period BSCW was used mainly to exchange information and messages related to the final report (that had to be written among several pairs with the same *client*). Since this *client*-centered organization cannot be observed in

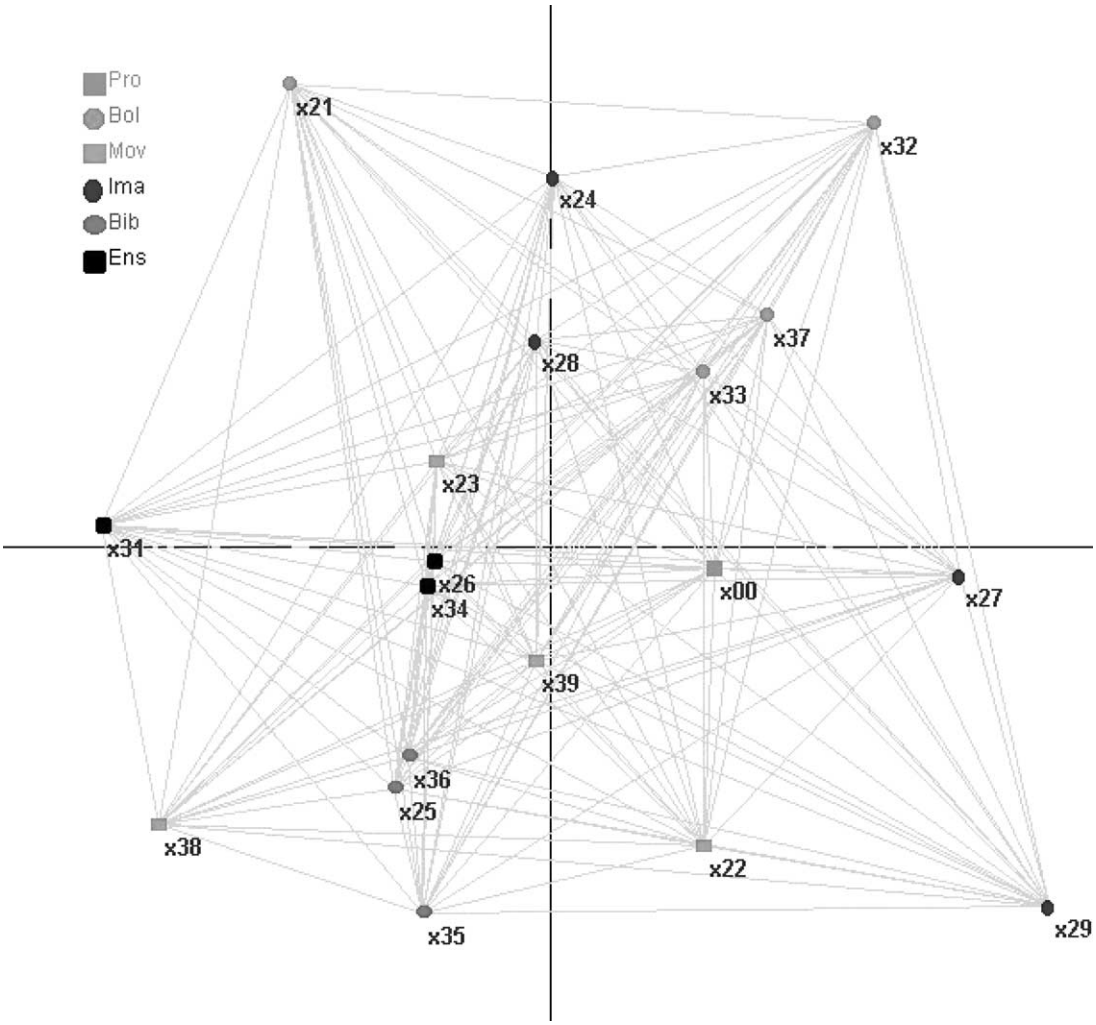

Fig. 3. Sociogram of the indirect relationships through BSCW network during the last period (writing of the final report). The teacher and the different *clients* are represented in different styles.

the sociograms corresponding to the rest of the subprojects (not shown here), we may conclude again that writing a joint report (i.e. having a common product) significantly increased collaboration through sharing information. This is confirmed by the following statements from the final group interview: "*[...] in this project we did use BSCW quite a lot to make appointments, to publish the things, to..., in this one we did, in the others we almost did not*"; "*We used BSCW so that the person in charge of putting the pieces together, could do it at home in a moment, and then the next day we met with the printed version and we were modifying it*."

Concluding this section, we can resume some of the findings that refer to the evaluation objective and point out how the proposed scheme helped to achieve the evaluation goal.

Results yielded by the quantitative analysis of the pre- and post-course questionnaires reflected an improvement in the student's perception of their own collaborative attitudes towards sharing

information. This positive result was partially confirmed by the rest of the methods, which helped to uncover some new aspects. Comparing the differences between the social networks of the three subprojects and the final one, we can conclude that BSCW was mainly used to get information from the teacher, and only in the last period students started to share information through it. A deeper qualitative analysis of student's answers to open-ended questions, and of the focus groups confirmed that this increase in the interchange of information was mainly due to practical reasons, and not so much to the aim of sharing their own knowledge. On the other hand, quantitative analysis showed that the general perception of the classroom collaborative environment improved dramatically after the course. In conclusion, we can say that the educational design almost obliged the students to practice new forms of collaboration that, in spite of not being as constructive as intended, helped to improve the overall classroom collaborative environment. The findings also show that the most positive period of the course was the final report writing, where collaboration took place at the client-level. As part of the formative evaluation process, this suggested to us the need of omitting the third subproject, so that the students can have more time for the client-level final project writing, and hopefully, to develop better collaboration habits and attitudes.

Regarding the evaluation method itself, we have also observed that sociograms can reveal interaction patterns that emerge both through the use of the computer (using computer logs) or directly (using the observer notes as source data). The discovered patterns can be confirmed by density and centralization scores, provided by the SNA tools. In order to explain more, pure qualitative tools like Nud*IST help to categorize the information coming from the qualitative data sources, such as questionnaires, focus groups or the observer annotations. Therefore, the combination of several sources of data results extremely convenient to avoid false or incomplete conclusions. However, we have seen that triangulation in mixed evaluation schemes may impose an unreasonable burden on researchers, in terms of time efficiency and usability. Our experience at the LAO project can suggest that the proposed tools together with the guidelines significantly alleviate this problem in CSCL systems evaluation.

5. Conclusions and future work

We have proposed a mixed evaluation method that aims at supporting the study of participatory aspects of CSCL environments, by including SNA techniques, quantitative statistics, and computer data logs into an overall qualitative case study design. The SNA indexes and the sociograms provided by SAMSA are of great value for detecting different collaborative patterns that emerge from classroom based activities, and the qualitative and quantitative studies help to discern these issues from the participants' perspective. This combination of sources of data and methods helps also to increase the reliability of the evaluation processes. The proposed scheme has been extensively tested during a three year period in a semi-presential university environment with considerable success and its main observations have been presented in this paper. We can argue that the proposed evaluation design is general enough, and its ideas can be adopted in CSCL environments different from the one that has been considered. This statement has been validated by our own experience in the evaluation of two distinct environments, one of them based on distance learning on an open university, and the other on a synchronous collaborative puzzle for kindergarten children (Martínez, 2003).

The proposed mixed method yields a more efficient approach than one based exclusively on qualitative data analysis. As it has been shown in the example, quantitative and social network analysis are able to detect "critical" issues that help to focus the qualitative evaluation on specific issues, instead of having to analyze all the qualitative data in order to extract conclusions. This increase in efficiency is also facilitated by the automatic tools proposed with the method. In this sense, QUEST has proved very efficient and flexible at designing, collecting and converting questionnaire data into adequate formats (both qualitative and quantitative). In addition, SAMSA allows for an easy and efficient processing of data coming from different sources and provides configurable and easy to visualize SNA results. The enhancement in usability and efficiency has been clearly observed during the three years of field work within the LAO project. As the proposed method, guidelines and tools evolved, our effort could mainly focus on the evaluation objectives, being also able to react with corrective actions and to support partially the formative evaluation process of the course teacher.

The use of XML to represent the interactions provides for the conceptual and operational integration of the different data under a common description. It is the core of a loosely coupled architecture, in which new modules can be added to deal with new sources of data. Additionally, developers can take advantage of the large offer of XML-based technologies found in the market. All these facts are increasingly important if we consider that a multifaceted evaluation scheme requires the use of multiple data sources, and that CSCL settings tend to be composed of a number of different and independent tools.

Several issues need still to be addressed. One of the most important refers to the fact that triangulation depends heavily on the expertise of the researcher/teacher. A deep knowledge of the context, a precise and careful design of the research objectives and categories, as well as a good use of the tools are required for a successful approach. Although several of these problems are clearly related to naturalistic evaluation approaches in general, we aim at providing a more refined set of guidelines as well as tools based on techniques of Artificial Intelligence.

Ongoing research deals with the integration of this perspective with the existing constructivist evaluation of DELFOS, which will allow us to reflect on the integration of individual and social aspects of learning. This could lead to consider new SNA techniques related to the roles of actors and their positions within the network.

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